Roles of Nano-Domains on Uniaxial Stress Dependence of Dielectric Properties of Ferroelectric Ceramics

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ABSTRACT

Roles of nano-domains on the uniaxial stress dependence of dielectric properties of ferroelectric ceramics in three different systems, i.e., BT-PZT, PMN-PT and PMN-PZT were studied. The dielectric properties were observed at room temperature under the compressive pre-stress levels up to 15, 22 and 5 MPa for BT-PZT, PMN-PT and PMN-PZT, respectively, using a homebuilt uniaxial compressometer. Dielectric constant of the BT-PZT ceramics increased significantly with increasing applied stress. Larger changes in the dielectric properties with the applied stress were observed in the PZT-rich compositions. However, for PMN-PT and PMN-PZT ceramic systems, changes in the dielectric properties with the stress were found to depend significantly on the ceramic compositions. The experimental results could be explained by both intrinsic and extrinsic mechanisms, involving domains, domain wall motions and de-aging phenomenon from the application of the compressive stress. Roles of different types of domains, i.e., micro-domains and nano-domains were also discussed.

Key words: Dielectric Properties, Ferroelectrics, Nano-Domains, Uniaxial Stress

INTRODUCTION

Among perovskite ferroelectric materials, barium titanate ($BaTiO_3$ or BT), lead titanate ($PbTiO_3$ or PT), lead zirconate titanate ($Pb(Zr_{1-x}Ti_x)O_3$ or PZT) and lead magnesium niobate ($Pb(Mg_{1/3}Nb_{2/3})O_3$ or PMN) ceramics have been investigated extensively and continuously since the late 1940s (Jaffe and Cook, 1971; Cross, 1996; Haertling, 1999; Moulson and Herbert, 2003). BT and PT, PMN, and PZT are representative perovskite normal ferroelectrics, relaxor ferroelectric, and piezoelectric prototypes, respectively, because of their excellent electrical properties. These ceramics possess distinct characteristics that make each of them suitable for different applications. Forming a composite of these ferroelectrics has been one of the techniques employed to improve the properties of ferroelectric ceramics for specific requirements for each application.

One of the most-studied piezoelectric compounds, $Pb(Zr_{0.52}Ti_{0.48})O_3$, a morphotropic phase boundary (MPB) compound of PZT, has great piezoelectric properties with a high Curie temperature (T_C) of ~390ºC. BT exhibits high dielectric constant and superior electrostrictive responses with a lower T_C (~ 120ºC) (Jaffe and Cook, 1971; Cross, 1996; Haertling, 1999; Moulson and Herbert, 2003). In addition, BT is mechanically superior to PZT (Chaisan et